MATHEMATICS CLASSROOM INTERACTIONS IN THE VIRTUAL SYNCHRONOUS ENVIRONMENT

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We compared classroom interactions during two episodes in a seventh grade virtual mathematics class. Both episodes were drawn from virtual live lessons utilizing different lesson layouts. We investigated how mathematical knowledge was negotiated in both episodes. The results show that the layout of live lessons had an effect on how students shared their thinking.

Keywords: Classroom Discourse; Technology

Technology is changing communication patterns as it introduces new forms of human interactions, asynchronously through emails, texts, blogs and discussion forums, and synchronously between large spatial distances. More remarkably, technology is altering how people experience education. In the U.S., the number of K-12 full-time virtual distant schools is growing exponentially (Barbour & Reeves, 2009). Mathematics too, is being encountered by K-16 students and teachers in virtual environments. Yet, research studies that carefully examine the content of interactions in such educational settings are rare. Such studies are necessary in order to unpack intricacies of mathematics learning and teaching specific to this type of environment. As Morgan and colleagues (2014) posited, there is an emergent need in the field to investigate online and mobile communication that are unique in mathematics contexts. Our goal of the case study we report here was to address this need. Our research aimed to unpack the nature of interactions taking place in one virtual mathematics classroom.

Background Literature

The utility of computer technology as a cultural tool for mediating knowledge construction has long been recognized (Saxe, 1991). The internet as a new form of technology-based learning medium, has also penetrated educational research in recent years. The range of reported research includes exploration of online teacher professional development, and online language programs (Bairral, 2009; Jonassen, 1986). Previously the main audience for online learning consisted of self-motivated adult professionals who clustered around a common interest. Asynchronous settings such as discussion forums and self-study online learning tools have provided the main context for learning among this population. Researchers and educators who explored the use of *hypermedia* or *hypertext* for online instruction have concluded that: (a) content representation in the web is not linear and can be hyper-linked; and that (b) it is beneficial for novices to access web automated knowledge representations that are pre-constructed by experts (Carlson, 1992). However, K-12 online or blended learning has entered the education arena and grown rapidly in the past five years. In comparison to the adult online learning format, synchronous lessons that are analogous to traditional brick-and-mortar classrooms represent a large part of online K-12 school curriculum. How mathematics is taught and learned in this environment has not been a subject of careful analysis. Arguably the most prominent and unique feature of a synchronous environment is how the teacher and students communicate about and with mathematics in the course of their interactions. As a starting point in developing a systematic research agenda surrounding online mathematics teaching and learning, a focus on unpacking synergistic interaction offers a productive scholarly venue.

Carlson (1992) provided a simple, but precise description of communication in a synchronous setting: "As a simple case example, participants are able to converse in dyads or triads with classmates not in close physical proximity; whereas, in the real classroom multiple, simultaneous

discussions quickly degenerate into a cacophony of voices" (p.57). A systematic study of language usage and the internet was conducted within the linguistics discipline. For synchronous group chats in particular, linguists have identified the delaying feature (Crystal, 2001). Crystal posited that lags in conversations interrupt the conversational turn in traditional face-to-face interaction, because in the virtual synchronous environment, turn-taking as seen on the screen was dictated by the software rather than the intentions of the end-users. However, Crystal and other linguists' studies of synchronous group chats were drawn from social networks rather than educational settings. Other features absent from synchronous group chat that are critical to the educational environment, such as facial expressions and physical body language, provide challenges for teachers in receiving cues from learners. The constraints of online interactions can certainly impact the quality of discourse taking place. Yet, we know little about specific features of the environment that may motivate classroom interactions and mathematics learning. To address this topic, we planned to study a seventh grade virtual mathematics classroom as the teacher delivered live lessons over the course of one academic semester. In this report, we chose two different live lesson layouts to study mathematics classroom interactions. Two specific questions guided our data analysis: (a) What is the nature of interactions between the teacher and students, and among students in the virtual synchronous mathematics classroom? (b) How do different settings of synchronous virtual mathematics instruction promote productive interactions and discussions about mathematics?

Methodology

Data was collected from a seventh grade mathematics teacher's class at a full-time virtual school. At the time of data collection, two mathematics classes were combined, and the total number of students was around 70. The researchers observed the teacher on a regular basis. A number of live lesson recordings were collected for virtual classroom interaction research.

Since our plan was to examine how the use of various features of the online lessons impacted modes of communication among the students and the teacher, we selected two episodes from two virtual live lessons to complete a comparative analysis. Each live lesson was an hour long. Both lessons shared a similar structure, consisting of four parts: (a) greeting and pre-assessment of previous content (approximately 15 minutes); (b) teacher-led instruction of the main learning objectives for the day (15 minutes); (c) students solving problem(s) and whole-class discussions about the problem(s) (15-20 minutes); and (d) the teacher offering a whole-class summary or students completing exit questions (10 minutes). The selected episodes concerned the third part of the lessons as students worked on assigned problems and discussed their solutions. Episode 1 was 13 minutes and 32 seconds long. Episode 2 was 10 minutes and 7 seconds long. We selected these two episodes to ground our comparison of the two sessions since the teacher's live lessons relied on different layouts, giving rise to contrasting interactions both between the teacher and students, and between students. The teacher's oral communications were transcribed and textual records were downloaded. Both sets of transcripts were then organized in the order in which they appeared in the screen.

Adobe Connect virtual lesson setting

The software used during both virtual live lessons was Adobe Connect. The software connected the teacher and students in real time in various locations. The students were "participants", and chat pods were the only communication tool they were allowed to use. The teacher was the "host" with access to audio, chat pods, drawing tools, and other presentational features. The teacher communicated with the students using primarily audio, whiteboard drawing and the chat pods.

In Episode 1, the teacher intended for the students to write an algebraic expression representing a real-life situation. The layout of this episode is shown in Figure 1. The teacher utilized three functions of Adobe Connect: the poll question to gather student responses at the beginning, a chat

pod labeled "EXPLAIN your thinking", and a "chalkboard" demonstration. In Episode 2, the content of the lesson concerned engaging students in solving two-step equations. In addition to the poll question and "chalkboard", two chat pods were utilized in the lesson: one labeled "QUESTIONS Only", and the other labeled "Responses to QUESTIONS" (Figure 2).

Figure 1:Layout of Episode 1

Figure 2:Layout of Episode 2.

Data Coding

The transcript was coded and analyzed in four phases by two researchers. First, we reorganized the individual exchanges by topics of conversation. Second, we segmented both episodes according to the questions that the teacher posed or the type of instructions that the teacher initiated. Then, in

each segment, we coded each exchange in three dimensions: (a) whether it was a response or initiation; (b) potential subjects of the exchange (e.g., whether it was addressing the teacher, students or everyone); (c) language functions of each exchange using the Analytical Framework of Peer-Group Interaction (Kumpulainen & Wray, 2002), including experiential (sharing how students experienced the class or the problem), interrogative (asking questions), instructive (providing instructions), affective (sharing feelings and attitudes), judgmental (agreeing or disagreeing), and argumentative (providing arguments). We also added a few language function codes that existed in the data, but not in the Analytical Framework. These codes are observational (providing observations, often about the mathematics), encouraging (students encouraging students), receptive (responding neutrally to a command or idea) and the unclear category. In our last step of data analysis, we identified the mathematical knowledge that was shared and negotiated in both episodes. Relations were mapped out according to the classroom interactions taking place in both cases.

Results

In this section, we will first present findings related to the observed differences between the two episodes according to the number, the sequence, and the nature of exchanges that took place relying on analysis of language functions. We will then discuss how mathematics was shared and negotiated during each discussion session.

Modes of interactions

42 students actively contributed to the chat pods in Episode 1, and 29 in Episode 2. Based on the teacher's instructional initiations, Episode 1 was divided into s segments according to the instructional moves of the teacher. In this episode, only one problem was discussed. Students were given time to solve and comment on the problem in the first two segments. The teacher then raised a few questions for students to consider as they explored the problem. During this time she prepared the virtual whiteboard (segment 3). Once the whiteboard was prepared, the teacher redirected the class to think about the context of the problem, and then led them through solving it (segments 4-5). This part was followed by a Q&A session, which lasted less than one minute (segment 6). Among eleven segments, students contributed 146 exchanges in total, including 20 exchanges that were *initiative* (e.g. "would the first month be 47 because of the 15 dollar fee?"), and 122 exchanges that were *responsive* (e.g. "the one time fee is important"), 112 of which were replies to the teacher's questions. In summary, the mode of interactions in Episode 1was dominated by teacher-student interactions, with a typical pattern of teacher verbal questions, followed by student text responses. The teacher served as the primary initiator of the interactions.

In Episode 2, two group chat pods, the QUESTIONS pod and the EXPLAIN pod, were accessible to students, and two problems were discussed. This episode consisted of five segments. The teacher first reviewed and demonstrated one student's solution (segment 1), followed by a three-minute session (segment 2) devoted to addressing students' questions raised during segment 1. She then posed another similar problem to the class and students were given time to think and respond (segment 3). Then, the teacher again modeled how the problem could be solved on the virtual whiteboard (segment 4) and then devoted over three minutes to respond to students' discussions in the chats (segment 5). In comparison to Episode 1, more evidence of the teacher's facilitation of discussions and student thinking was present in Episode 2; the layout of the "QUESTION" and "Responses to QUESTIONS" pods provided a platform for students to raise questions and invite peer discussions, and for the teacher to facilitate student-student discussions. The teacher spent more than six minutes addressing students' discussions in Episode 2, whereas the teacher spent less than one minute in Q&A during Episode 1. In total, students contributed 65 exchanges with 34 of these exchanges contributed in response to peer comments. This evidenced a higher proportion of student-student interaction compared to the first episode.

Sequence of interaction

In the sessions that we have examined, the sequence of virtual interactions heavily depended on how the conversations were initiated by the teacher (e.g., yes/no questions, comments of the mathematics problem) and the opportunities for responding to the initiation (e.g., the availabilities of chat pods in the layout). When only one chat pod was available in Episode 1, the teacher modeled the solutions of the problem. She was able to maintain a sequential and focused teacher-student interaction by posing closed or dichotomous questions as exemplified in the excerpt below.

123. *T*: If I am paying something everything month, what operation is gonna help achieve that?
124. *Mel*:32*m
125. *Des*: multiplication
126. Mak: multiplication
... ...
140. *Pri*: Multiply
141. *Nic*: I added instead of multiplying OOPS

In the above exchange from lines 124 to 141, students were directly responding to the teacher's question in line 123, though the responses were presented in slightly different ways. Indeed, the interaction was highly sequential in the sense that exchanges could be traced naturally without disruptions. It was also highly spontaneous, since almost twenty exchanges appeared in the chat within a few seconds. Yet, this interaction mode took place only in Episode 1, when dichotomous or closed questions were posed, and responses required short-typed words.

In Episode 2, such a sequential and simultaneous interaction mode was not evident. Instead, interactions between the teacher and students or among students were highly non-sequential and overlapping. Students now had two different chat pods for interaction instead of one, as illustrated in Figures 1 and 2. Because the two chat pods were designated for student questions and student responses to those questions, they promoted student-student interaction in comparison to promoting only teacher-student interaction as in Episode 1. The sequence of interaction became more complex as demonstrated in the excerpt below.

25. (Audio) *T*: Let's do another one I'm gonna throw at you and then we talk about it. Ok?
26. (QUESTION) *Al*: I just used mental math is that okay..?lol
27. (Audio) *T*: How about -2y-4
28. (QUESTION) *Des*: I am confused NO NEVER MIND
29. (QUESTION) *Miv*: what is it called when you put a line in the equal sign
30. (EXPLAIN) *Ken*: xD
31. (Audio) *T*: Try to specific, Des. We will try to help you.
... ...
35. (EXPLAIN) *Sha*: Al-That is fine! As long as you get the right answer. :)

Within these eight exchanges, several conversations were taking place: (a) the teacher was posing a new problem (#25, 27); (b) two students were asking separate questions (#26, 29), one of whom received a student response in #35; and (c) another student was expressing confusion (#28), which caught the teacher's attention in #31. Meanwhile, Ken (#30) may have been responding to either the teacher or the use of the caps lock by Des (#28). We use *linear* to describe the interaction in the Episode 1 excerpt, and *multi-directional* to describe this interaction in the excerpt from Episode 2. Students raised questions in Episode 1, but due to the large number of chat messages in a single chat pod, the questions became invisible; they did not become a source of contemplation or discussion, and never disrupted the lesson flow. In contrast to Episode 1, questions in Episode 2 had a designated place during the teacher's instruction, which made it easier for students and the teacher to notice questions thus providing an available space for group discourse.

Language Functions

Examining the language functions of the texts of student chats, two features distinguished the quality of interactions in the two episodes. First, the proportion of student-self initiated conversations was greater in Episode 2 than in Episode 1. Students openly shared their experiences of the problem (*experiential*), commented on characteristics of the problem (*informative*), and asked questions (*interrogative*). Second, students in Episode 2 engaged in each other's problem solving processes. Some students questioned and answered, commented, and judged each other's mathematics while other students took a lead on sharing information about the problem.(e.g. "*Don't forget, the 4 isn't negative*"). Texts were informative, interrogative, and judgmental inEpisode 2, while texts were mostlyreceptive (e.g., yes, ok), observational, and addressing the teacher in Episode 1.

Taken-and-shared mathematics

In the first half of Episode 1, the teacher asked students to discuss the problems. The teacher's questions provided ample opportunities for diverse student responses, though interactions were one-directional, short, and sequential as the teacher responded to the majority of students' questions or answers. Thus the primary source of knowledge was the teacher who verified answer and confirmed accuracy of responses. Some of the important mathematical information that the individual students provided during the discussion went un-noticed or un-acknowledged. Even more importantly, discussion around these different ideas was not pursued in places where conflicting views on the same question were expressed. Instead, the teacher directed the class, judged the answers, and moved on to a new problem or task. This was partly because student replies in the chat pod were quick, rich and non-uniform, which made it difficult for the teacher to closely follow each contribution. As shown in Figure 3, the content of mathematics discussed became rather linear.
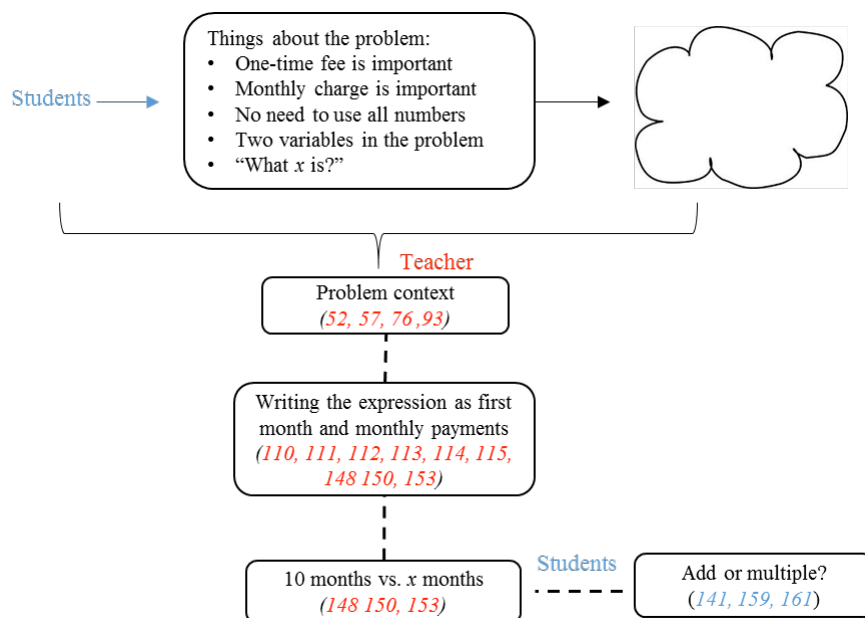
Figure 3: Map of knowledge shared in Episode 1. Blue indicates student contributions. Red indicates teacher contributions.

In Episode 2, mathematical knowledge shared was what we refer to as the "popcorn" style (Figure 4); which characterized features of open and simultaneous discourse. For instance, while the teacher was demonstrating the procedure for solving an equation on the "chalkboard", students'
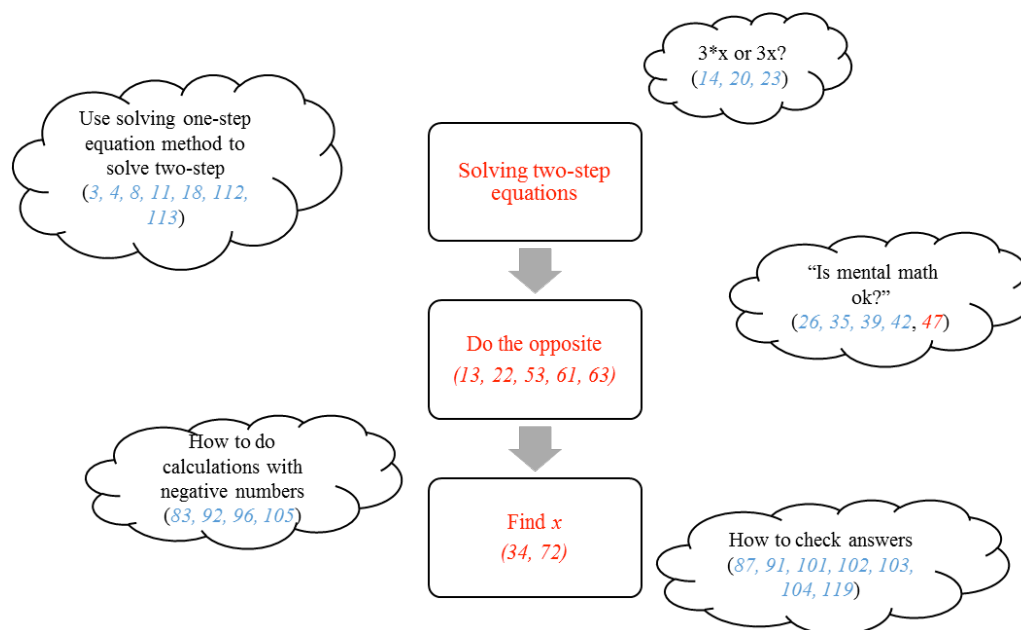
Figure 4: Knowledge shared and negotiated in Episode 2: popcorn style. Blue indicates student contributions. Red indicates teacher contributions.

discussion in the chat pods did not necessarily relate to each step of the teacher's demonstration. The students' comments often corresponded to other issues related to the problem, such as how and when mental arithmetic can be an effective approach to solve two-step equations, negative operations, and the conventions of algebraic expressions, which were separate from the teacher's original agenda of demonstrating the procedure. The content presented by the class was multidirectional. Students who were sitting in front of the computer could follow different "pops" of knowledge shared on the screen and could comment on those that they found interesting or useful. In this episode, students were sharing and negotiating different elements of solving two-step equations and the teacher was no longer the dominating source of knowledge. Instead of acting independently from the students by focusing on her own agenda of the problem's procedure as in Episode 1, the teacher depended on student responses to guide her facilitation of the discussion in Episode 2. The teacher's organization of the chat pods in Episode 2 allowed for greater opportunities for student thinking to be expressed, and for the teacher to have a greater role in facilitating the students' discussion.

Discussion

The purpose of this study was to explore the nature of interactions within online synchronous mathematics lessons resulting from different features of these lessons. By mapping out the transcripts of two episodes, it became evident that classroom interactions in a synchronous environment can be different when the layouts of the classroom were changed. These differences include changes from (1) teacher-students interactions to student-student interactions; (2) a linear conversation sequence to a multi-directional conversation sequence; and (3) students mainly responding to the teacher to interacting with each other. Consequently, these changes effected how students discussed and negotiated mathematics. The literature has documentedthe major feature of virtual interaction as non-sequential and overlapping (Crystal, 2001). Yet, our data showed that a synchronous lesson can be a highly structured lesson guided by the teacher, and communication quite spontaneous and sequenced as it would be in traditional brick-and-mortar classroom interactions. However, as soon as the layout of the lesson changed as in Episode 2, the interactions became non-sequential.

Our results indicate that the teacher's ability to closely monitor the students' interactions and mathematical discussions simultaneously in different chat pods helped effectively initiate and facilitate generative discourse among students. When opportunities were provided for students to negotiate their mathematical knowledge with one another, as seen in Episode 2, the dominating role of the teacher's mathematics was challenged. This issue raises several important questions that merit careful attention from the research community, some of which include: How could mathematics teachers synthesize multiple sources of students' mathematics to advance students' discussions towards building generalizations and identifying important mathematical structures? What type of knowledge might a mathematics teacher need to develop in order to do so? How might teachers manage social interactions using the chat pods or other functions in the environment so as to gear students towards mathematics learning and knowledge construction (Yackel & Cobb, 1996)? With a rapid increase in the desire to converge learning environments towards a virtual paradigm, it seems inevitable that our understanding of how such an educational setting might best be organized and moderated to allow for development of inquiry skills and conceptual understanding of mathematical ideas. The questions we raised here relate explicitly to this agenda.

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